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(54) **Passive bipolar arc control system and method**

(57) A method and system for controlling arcs in a DC sputtering system with a passive circuit is presented. The arc control system includes a sputtering chamber that houses an anode and a sputtering target formed from a target material and serving as a cathode. A DC power supply provides a DC voltage between the cathode and anode such that a cathode current flows from the anode to the cathode. A resonant network is coupled between the DC power supply and the chamber. The resonant network has sufficient Q so that in reaction to an arc, the cathode current resonates through zero, causing a positive voltage to be applied between the cathode and anode. A reverse voltage clamp is coupled across the resonant network to clamp the cathode voltage to a predetermined reverse voltage. The reverse cathode voltage inhibits subsequent arcing by positively charging insulated deposits on the sputtering target. The arc control system limits the quantity of energy that is dissipated by the arc.

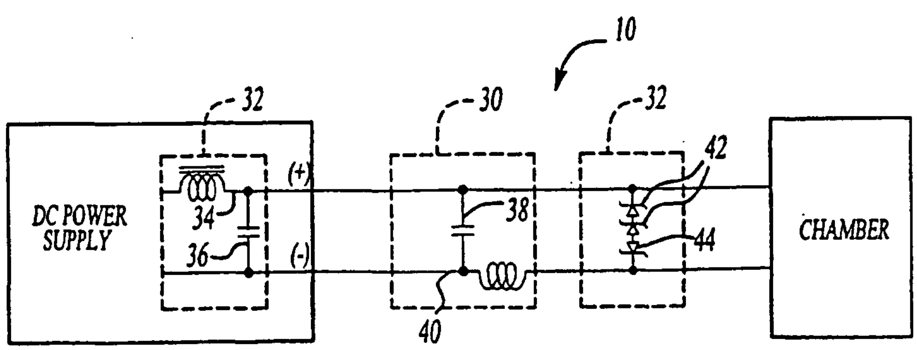

Fig-3

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portion of the resonant waveform to drive the cathode and reverse charge the target surface. Thus reverse current of the network is allowed to flow unimpeded to the cathode. This reverse current then charges the cathode to a clamped positive voltage.

[0011] For a more complete understanding of the invention, its objects and advantages, reference may be had to the following specification and to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Figure 1 illustrates an exemplary workpiece having mousebites;
Figure 2 is a block diagram of a sputtering system constructed in accordance with the teachings of the invention;
Figure 3 is a schematic diagram of a presently preferred embodiment of the invention;
Figure 3A is a schematic diagram of a voltage clamp;
Figure 3B is a schematic diagram of another voltage clamp;
Figure 4A illustrates a sputtering system during a voltage reversal;
Figure 4B illustrates a conventional sputtering system during a voltage reversal;
Figure 4C illustrates a sputtering system in accordance with the principles of the present invention during a voltage reversal; and
Figure 5 is a signal diagram showing the cathode current and voltage waveforms associated with an arc.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0013] Referring to Figure 2, a DC sputtering system 10 according to the present invention is shown. In the presently preferred embodiment of the invention, the DC sputtering system 10 uses a DC sputtering process to deposit a coating on a workpiece 16. Although, the workpiece in the present embodiment is an optical disk storage media such as CDs and DVDs, it is within the scope of the invention to coat other items such as drill bits, glass panels, toys, cutting tools, optical equipment for any substrate, or a sputtered thin film. This process is unusual in that there typically is about 50 percent atmosphere in the sputtering chamber at the beginning of the deposition process. The oxygen and nitrogen of the air may convert some aluminum deposition to a Al_2O_3 and AlN deposition for the first part of the run. During the early portion of this process, arcing may occur due to outgassing, atmosphere contamination, etc.

[0014] The sputtering system 10 includes a sputtering chamber 12 that provides a controlled environment for the deposition process. A vacuum pump 11 is typically used to maintain the sputtering chamber 12 at a controlled pressure. The workpiece 16 may be a CD, DVD, cutting blade, or other item to be coated. A sputtering target 18, configured as a cathode, serves as a source of material for the coating. In the presently preferred embodiment the target 18 is formed from aluminum, although other suitable materials and alloys such as Gold, Si, Ta, B, and Ti may be used. Another piece of conductive material within the sputtering chamber 12 serves as an anode 20. The cathode 18 and anode 20 are coupled to a DC power supply 24 which supplies electrical energy for inducing a plasma within the sputtering chamber 12. In the presently preferred embodiment the atmospheric gas introduced at the start of the process is a contaminant. A controlled amount of a sputtering gas, for providing anions that flow within the plasma, is also supplied to the sputtering chamber 12. Typically argon or another noble gas is used as the sputtering gas.

[0015] For this particular application of the invention, wherein an optical disk is coated, a pair of shields are included in the chamber 12 for masking the outer and inner edges of the optical disk that is used as the workpiece 16. The shields provide well defined outer and inner radii for the optical disk. An outer shield 14 is positioned between the target material 18 and the optical disk 16 to prevent the deposition of coating material on the outer edge. An inner shield 17 is likewise positioned to prevent coating of the inner edge of the optical disk.

[0016] The DC power supply 24 provides electrical energy for the sputtering process. The power supply 24 converts unregulated AC line power to regulated DC power suitable for powering the sputtering system 10. In the presently preferred embodiment of the invention, the DC power supply 24 is a switch mode power supply, however, the scope of the invention is not limited by the type of power supply. For example, other types of power supplies such as SCR and diode-transformer power supplies may be used. The positive 26 and negative 28 outputs of the DC power supply 24 are coupled to the anode 20 and cathode 18, respectively. The power supply 24 provides the required voltage/current to the sputtering chamber 12. As will be recognized by those skilled in the art, the nominal voltage is to be suitable for the target material and sputtering operation to be performed. Therefore, the scope of the invention includes sputtering processes employing a wide range of voltages. A resonant network 30 and voltage clamp 32 are connected between the DC power supply 24 and the cathode 18 and anode 20. The resonant network 30 stores electrical energy that drives a voltage reversal at the cathode 18 and anode 20 during an arc event. Although, the resonant network 30 is illustrated as being separate from the power supply 24, it is within the scope of the invention to integrate the resonant network 30 into the power supply 24. Indeed, as will be subsequently explained, the performance of the resonant network 30 is correlated to the output filter of power supply 24. The

[0023] After the arc is extinguished, the cathode current continues to resonate. As the cathode current 48 passes through zero amps, the cathode voltage 50 re-establishes the sputtering voltage and power.

[0024] Referring to Figs. 4A, 4B, and 4C, the state of the sputtering system 10 during a voltage reversal is contrasted with conventional sputtering systems. Fig. 4B illustrates the operation of a conventional sputtering system during a voltage reversal. Fig. 4C illustrates the operation of the presently preferred embodiment of the sputtering system 10 during a voltage reversal. During normal operation, prior to an arc occurring, target material sputtered off from the cathode 18 forms a coating 19 on the workpiece 16. As the coating 19 is formed, a low-level negative charge accumulates within the coating 19 as well as along the surface of the coating 19. When a voltage reversal occurs, the voltage on the cathode 18 swings positive relative to the anode 20. Positive anions that previously were attracted to the cathode 18 are increasingly repelled as the reverse voltage increases in magnitude.

[0025] In conventional sputtering systems (see figure 4B), the positive anions instead of flowing towards the cathode 18, increasingly flow towards the negatively charged workpiece 16. As the anions flow towards the workpiece 16, they are attracted towards the outer and inner edges of the coating 19 due to the high electric fields present in those regions. When the anions strike the coating 19, momentum transfer occurs causing portions of the coating 19 to be back sputtered, with the majority of the sputtering occurring along the edges. Mousebites 9 are exhibited as the back sputtering along the edges of the coating 19 continues. The back sputtered coating 19 which comprises mainly aluminum with a smaller proportion of Al_2O_3, is deposited on the inner surfaces of the sputtering chamber 12 including the shields 14 and 17, and the cathode 18.

[0026] In the presently preferred embodiment of the sputtering system 10, the magnitude of the voltage reversal is clamped at a sufficiently low voltage to prevent the flow of positive anions towards the negatively charged workpiece 16. Since anions do not strike the coating 19, the mousebites 9 that plagued conventional sputtering systems are prevented from occurring in the presently preferred embodiment.

[0027] The arc control system of the present invention minimizes the time to recover from an arc, thereby increasing the proportion of process time during which deposition of material occurs. Additionally, the system prevents the formation of mousebites during an arc.

[0028] Also, the arc control system decreases the arc energy that is dissipated in the chamber, thereby reducing defects in the workpiece. In addition, the period of time before subsequent arcs occur is lengthened, again increasing the process time during which deposition of material occurs.

[0029] Further, the arc control system is designed with a comparatively small number of passive components.

[0030] Thus it will be appreciated from the above that as a result of the present invention, an arc control method for DC sputtering systems is provided by which the principal objectives, among others, are completely fulfilled. It will be equally apparent and is contemplated that modification and/or changes may be made in the illustrated embodiment without departure from the invention. Accordingly, it is expressly intended that the foregoing description and accompanying drawings are illustrative of preferred embodiments only, not limiting, and that the true spirit and scope of the present invention will be determined by reference to the appended claims and their legal equivalent.

Claims

1. An arc control system for responding to an arc in a DC sputtering system, comprising:

   a sputtering chamber that houses an anode and a sputtering target formed from a target material and serving as a cathode;
   a DC power supply to provide a direct current cathode voltage such that a cathode current flows through the anode and the cathode;
   a resonant network coupled between the DC power supply and the chamber, the resonant network having a Q such that in reaction to the occurrence of an arc, the cathode current resonates to a reverse current level; and
   a reverse voltage clamp coupled across the resonant network to clamp the cathode voltage to a predetermined clamp voltage.

2. The arc control system of Claim 1 wherein the resonant network is a capacitor-inductor filter.

3. The arc control system of Claim 1 wherein the reverse voltage clamp comprises at least one zener diode in series with a reverse biased diode.

4. The arc control system of Claim 1 further comprising a forward voltage clamp in series with the reverse voltage clamp, wherein the reverse voltage clamp comprises at least one bi-directional zener diode and the forward voltage clamp comprises at least one unidirectional zener diode.

5. The arc control system of Claim 1 wherein the DC power supply is selected from the group of: SCR power supplies, switchmode power supplies, and diode-transformer power supplies.

6. The arc control system of Claim 1 wherein the predetermined clamp voltage is less than a backsputtering voltage.

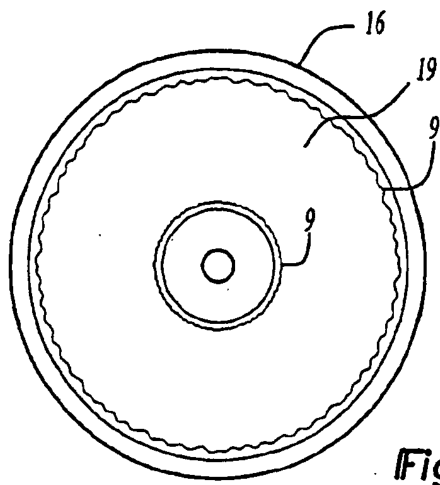

Fig-1

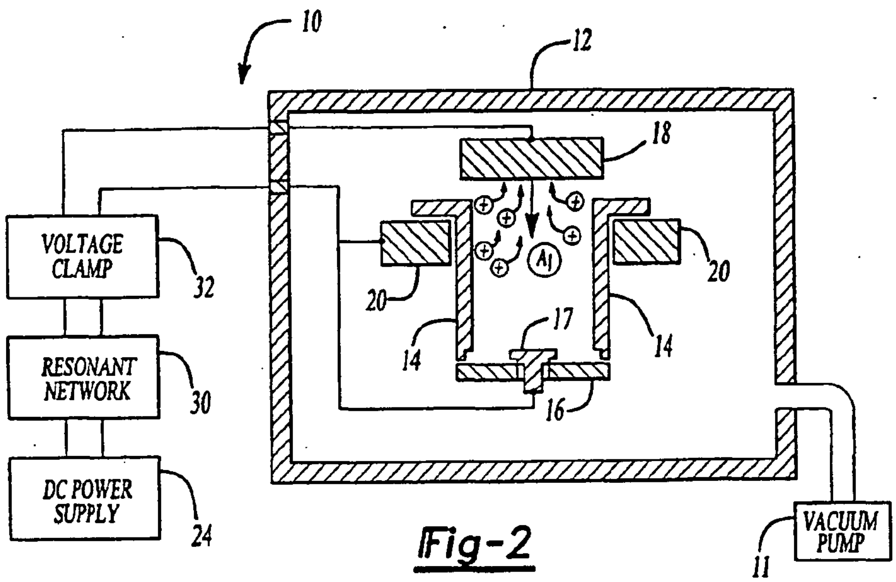

Fig-2

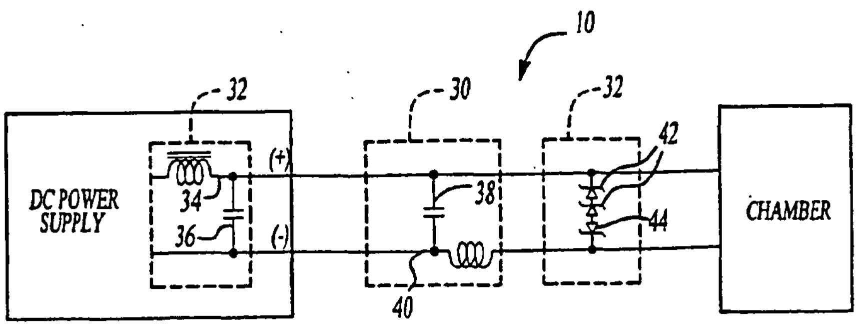

Fig-3

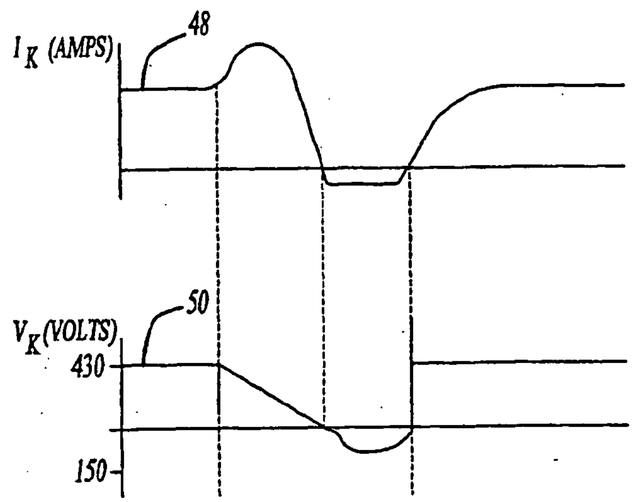

Fig-5

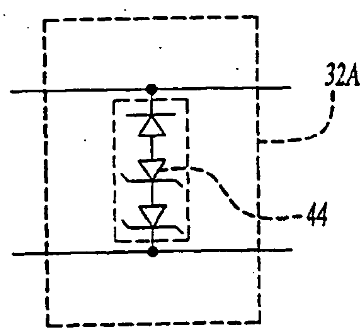

Fig-3A

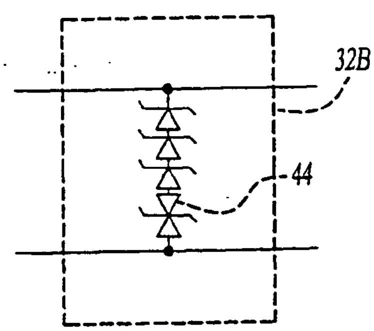

Fig-3B